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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

INVESTIGATION OF THE SPINNING

AND TUMBLING CHARACTERISTICS OF A 1/25-SCALE

MODEL OF THE LOCKHEED XFV-1 AIRPLANE IN THE

LANGLEY 20-FOOT FREE-SPINNING TUNNEL

By Henry A. Lee

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

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SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel on a 1/25-scale model of the Lockheed XFV-1 airplane to determine the effects of control setting and movement upon the erect-spin and recovery characteristics for a range of airplane loading conditions. A windmilling propeller was simulated on the model for some of the tests. The investigation included determination of the size of tail parachute required for emergency recovery from demonstration spins. The tumbling tendencies of the model were also investigated.

The results indicated that any erect or inverted spin obtained on the airplane will be satisfactorily terminated if recovery is attempted by full rudder reversal accompanied by simultaneous lateral and longitudinal movement of the stick to neutral. The model test results showed that an 11.5-foot flat-type tail parachute (drag coefficient approximately 0.73) with a 27.5-foot towline will be effective as an emergency spin-recovery device during demonstration spins of the airplane. The model results also indicate that the airplane will not tumble for any loading condition indicated possible.

INTRODUCTION

In accordance with a request of the Bureau of Aeronautics, Department of the Navy, an investigation was performed in the Langley 20-foot free-spinning tunnel to determine the spin, spin-recovery, and tumbling

characteristics of a 1/25-scale dynamic model of the Lockheed XFV-1 air-. plane. The XFV-1 is a vertically rising airplane having a conventional tapered wing with an X-shape tail and uses a large-diameter dual-rotation propeller. All controls of the airplane are on the tail.

The erect-spin and recovery characteristics were determined with propellers off and with windmilling propellers simulated. Two loading conditions were investigated and corresponded to the approximate extremes in loadings attainable on the airplane. Brief tests were made to determine the effect of wing-tip pods on the spin and spin-recovery characteristics with rudder fixed at neutral. The size of tail parachute required for emergency recovery from the spin was also determined. The tumbling characteristics of the model were investigated with windmilling propellers simulated.

SYMBOLS

b	wing span, ft
S	wing area, sq ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes respectively, slug-ft^2
$\dfrac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\dfrac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter

$\dfrac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

ρ air density, slugs/cu ft

μ relative density of airplane, $m/\rho Sb$

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ angle between span axis and horizontal, deg

V full-scale true rate of descent, ft/sec

Ω full-scale angular velocity about spin axis, rps

σ helix angle, angle between flight path and vertical, deg (for the tests of this model, the average absolute value of the helix angle was approximately 2.8°)

β approximate angle of sideslip at center of gravity, deg (sideslip is inward when inner wing is down by an amount greater than the helix angle)

APPARATUS AND METHODS

Model

The 1/25-scale model of the Lockheed XFV-1 airplane was furnished by the Bureau of Aeronautics, Department of the Navy, and was prepared for testing by the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model as tested is shown in figure 1. Photographs of the model in the clean condition and with wing-tip pods on are shown as figures 2 and 3, respectively. Dimensional characteristics of the airplane as simulated by the model are presented in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 20,000 feet ($\rho = 0.001267$ slug/cu ft). A magnetic remote-control mechanism was installed in the model to actuate the controls for the recovery attempts and to open the parachute for the parachute tests. Sufficient moments were exerted on the controls for the recovery attempts to reverse them fully and rapidly.

Lateral, longitudinal, and directional controls were combined in
the four control surfaces on the X-shape tail. Longitudinal and direc-
tional controls were obtained by deflection of all the control surfaces
up and down or right and left, respectively, and lateral control was
obtained by deflection of the control surfaces differentially. In this
paper, control deflections for longitudinal, lateral, and directional
control will be referred to, for simplicity, as elevator, ailerons, and
rudder deflections, respectively.

The windmilling propeller was simulated on the model by setting four
fins in the propeller disk, two parallel to the plane of symmetry and two
normal to the plane of symmetry. The fin area used to simulate the wind-
milling propeller was calculated according to the methods given in refer-
ence 1. A drawing showing the propeller as simulated for a blade angle of
70° is shown in figure 4. This value of 70° was selected as the maximum
propeller blade angle on the basis of previous tests of a spin-tunnel model
which used the same type of propeller. Ordinarily propellers are not
simulated on spin models because unpresented test results have shown that
conventional windmilling propellers have little effect on model spin or
spin-recovery characteristics. The propeller was simulated on this design,
however, because the XFV-1 propeller is large and it appeared possible
that the propeller might affect the spin and recovery characteristics of
the model.

Wind-Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel,
the operation of which is generally similar to that described in refer-
ence 2 for the Langley 15-foot free-spinning tunnel.

Spin tests.- The launching technique for the model spin tests has
been changed from that described in reference 2 in that the model is now
launched by hand, with rotation, into the vertically rising airstream.
After a number of turns in the established spin, recovery is attempted by
moving one or more controls. After recovery the model dives into a safety
net. In those instances when the model does not recover it is lowered into
the safety net. A photograph of the model during a spin is shown as
figure 5.

The spin data presented were obtained and converted to corresponding
full-scale values by methods described in reference 2. The turns for
recovery were measured from the time the controls were moved, or the para-
chute was opened, to the time the spin rotation ceased and the model dived
into the net. When the model recovered without rudder movement, with the
rudder with the spin, the results were recorded as "no spin."

Spin-tunnel tests are usually made to determine the spin and recovery
characteristics of the model at the normal spinning control configuration

(elevator full up, ailerons neutral, and rudder full with the spin) and
at various other aileron-elevator control combinations including zero
and maximum deflections. Recovery is generally attempted by rapid full
rudder reversal alone, or when necessary, accompanied by movement of other
controls. Tests are also performed to evaluate the possible adverse
effects on recovery of small deviations from the normal control configu-
ration for spinning. For these tests, the ailerons are set at one-third
of the full deflection in the direction conducive to slower recoveries
and the elevator is set at two-thirds of its full-up deflection or full
up, whichever is conducive to slower recovery. Recovery is attempted by
rapidly reversing the rudder from full with the spin to two-thirds against
the spin either alone or in conjunction with movement of other controls.
This control configuration and manipulation is referred to as the "crite-
rion spin." Recovery characteristics of the model are considered satis-
factory if recovery from this criterion spin required $2\frac{1}{4}$ turns or less.
This value has been selected on the basis of full-scale-airplane spin-
recovery data that are available for comparison with corresponding model
test results.

The full-scale rudder-pedal force necessary to move the rudder for
recovery in a spin was determined from model tests. For these tests,
tension in the rubber band which pulls the rudder against the spin was
adjusted to represent a known value of the model rudder hinge moment
about the rudder hinge line and recovery tests were run. The tension
was reduced systematically until the turns for recovery began to increase.
The model rudder hinge moment at this point was then converted to a full-
scale rudder-pedal force at the equivalent altitude at which the tests
were run.

For the spin-recovery parachute tests, the minimum-size tail para-
chute required to effect recovery within $2\frac{1}{4}$ turns was considered satis-
factory. For these tests, the parachute was opened for the recovery
attempts by actuating the remote-control mechanism and the rudder was
held with the spin so that recovery was due entirely to parachute action
alone. For the present tests, the towline was attached to the model at
the extreme rearward point on the fuselage, and the parachute was packed
at the base of the top right tail surface on the inboard (right in a right
spin) side just above the fuselage. For the model tests, locating the
packed parachute in the location indicated did not affect the established
spin. A rubber band holding the packed parachute to the model was
released and the parachute was opened merely by the action of the air-
stream. For the full-scale parachute installation it would be desirable
to mount the parachute pack within the airplane structure if possible,
and it is considered desirable that a positive ejection mechanism be
employed to eject the parachute and to insure against the possibility of
the parachute fouling on the landing gear.

Tumbling tests.--Two methods of launching were employed in determining the susceptibility of the model to tumbling. For one method, the model was held at an attitude approximately 180° to the vertical airstream and was then dropped, thus simulating a whip-stall condition. For the second method of launching, the model was held approximately 180° to the airstream and then given an initial pitching rotation by hand. The resulting motions were observed and photographed. If a model tumbles with either method of launching, it is taken as an indication that the corresponding airplane can tumble although the airplane would be more likely to tumble if the model started tumbling when launched without pitching rotation. If the model stops tumbling after being launched with initial pitching rotation, the results are interpreted to mean that the corresponding airplane will not tumble.

PRECISION

The model spin test results presented are believed to be true values given by the model within the following limits:

α, deg . . . . ± 1
ϕ, deg . . . . ± 1
V, percent . . . . ± 5
Ω, percent . . . . ± 2
Turns for recovery:
  From motion-picture records . . . . $\pm 1/4$
  From visual·observation . . . . $\pm 1/2$

The preceding limits may have been exceeded for some of the spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

Comparison between model and full-scale results in reference 3 indicated that model tests satisfactorily predicted full-scale recovery characteristics approximately 90 percent of the time and for the remaining 10 percent of the time the model results were of value in predicting some of the details of the full-scale spins. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 3 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models, the higher rate of descent of airplane or model, however, being generally associated with the smaller angle of attack. This comparison was made primarily for conventional airplane designs, however, and may not be strictly applicable to the XFV-1.

Because it is impracticable to ballast the model exactly and because of inadvertent damage to the model during tests, the measured weight and mass distribution of the XFV-1 model varied from the true scaled-down values within the following limits:

Weight, percent . . . . 0 to 1 low
Center-of-gravity location, percent $\bar{c}$ . . . . 1 forward to 5 rearward
Moments of inertia:
  I_X, percent . . . . 1 high to 9 high
  I_Y, percent . . . . 4 high to 2 low
  I_Z, percent . . . . 2 high to 2 low

The accuracy of the measurements is believed to be within the following limits:

Weight, percent . . . . ± 1
Center-of-gravity location, percent $\bar{c}$ . . . . ± 1
Moments of inertia, percent . . . . ± 5

Controls were set with an accuracy of $\pm 1^\circ$.

TEST CONDITIONS

The mass characteristics and inertia parameters for loadings possible on the airplane and for the loadings tested on the model are shown in table II and plotted in figure 6. Unless otherwise indicated, all tests were conducted with wing-tip pods installed.

The maximum control deflections (perpendicular to the hinge lines) used in the tests were as follows:

Rudder, deg . . . . 10 right, 10 left
Elevator, deg . . . . 30 up, 10 down
Ailerons, deg . . . . 30 up, 30 down

The control deflections are additive and a maximum control deflection of 70° is possible.

The spin characteristics of the model were investigated with the propeller off and with the simulated propeller (fin area) installed. As has been indicated previously, the fin area was installed to simulate the windmilling propeller with power off for a blade angle of 70°. No attempt was made to duplicate any power conditions. The effect of the wing-tip pods and the effect of mass-loading variations on the spin characteristics of the model were also determined. The tumbling characteristics were investigated with the simulated propeller and wing-tip pods installed.

RESULTS AND DISCUSSION

The results of the model spin tests are presented in charts 1 to 3 and in table III. The model data are presented in terms of full-scale values for the airplane at an altitude of 20,000 feet. Inasmuch as similar results were obtained when the model was launched with spinning rotation either to the pilot's right or left, all spinning results are arbitrarily presented for rotation to the pilot's right. As previously stated, no attempt was made to simulate power conditions, and for the tests with propellers simulated the discussion that follows applies only for the propeller-windmilling case.

Erect Spins

The erect-spin and recovery data obtained for the two approximate extremes in loading possible on the airplane as investigated on the model are presented in charts 1 to 3. Results for the landing-pods-off loading (loading 1 in table II and fig. 6) with propellers removed and with windmilling propellers at a 70° blade angle simulated are presented in charts 1 and 2, respectively. The results for the take-off loading with fuel and ammunition (loading 15 in table II and fig. 6) with windmilling propellers at a blade angle of 70° simulated are presented in chart 3. The results for the loading conditions investigated with the simulated windmilling propellers installed or removed were generally similar in that the model would spin only for a few combinations of control settings with the elevator neutral or up and ailerons neutral or with the spin. The model did not spin for aileron-against (stick left in a right spin) or elevator-down control settings. The flatest spins were obtained with windmilling propellers simulated for the criterion-spin control configuration, ailerons 1/3 with and elevators 2/3 up. Recoveries were not always satisfactory by reversal of rudder to only 2/3 against the spin for this control setting. For airplanes having mass characteristics similar to the XFV-1, it would ordinarily be expected that ailerons with the spin (stick right in a right spin) would tend to prevent the spin and that ailerons against the spin would tend to promote the spin (ref. 4). The reverse was true for the XFV-1, which has all its controls on the tail, probably because the controls when deflected as ailerons produced little rolling moment because of their proximity to the plane of symmetry. In addition, the lower control surfaces, which are unshielded in the spin and are thus the most effective controls at spinning attitudes, would tend to produce a greater pro-spin yawing moment when the ailerons were set with the spin than when the ailerons were set against the spin. Thus placing ailerons with the spin is equivalent to providing a greater rudder deflection with the spin for the lower control surfaces. On the basis of this analysis, it appeared desirable that rudder reversal be accompanied by at least neutralization of the ailerons. Also, because elevator-down settings had

a slightly favorable effect and inasmuch as neutralization of the stick both laterally and longitudinally might be the least confusing control manipulation for the pilot on the corresponding airplane, model tests were made for which rudder reversal to 2/3 against the spin was accompanied by neutralization of both ailerons and elevator. This control manipulation gave satisfactory recoveries. Inasmuch as the loadings and propeller conditions investigated represent the approximate extremes attainable on the airplane, it would thus appear that rudder reversal accompanied by neutralization of ailerons and elevator should satisfactorily terminate any erect spins obtained on the airplane.

Brief tests were made with the wing-tip pods installed to determine the aerodynamic effect of the pods on the spin and recovery characteristics. The results, not presented in charts, indicated that the wing-tip pods did not have any appreciable aerodynamic effect.

Inverted Spins

Inasmuch as the XFV-1 airplane is a design which incorporates an equal amount of fin and rudder area above and below the fuselage center line, inverted spin tests were not conducted because spin-tunnel experience indicated that inverted-spin and recovery characteristics would be essentially the same as the erect-spin and recovery characteristics. Thus, for any loading condition indicated possible on the airplane in table II, any inverted spins obtained should be satisfactorily terminated by full movement of the rudder to oppose the spin rotation (rudder against the inverted spin) and simultaneous movement of the stick laterally and longitudinally to neutral.

Control Forces

The discussion of the results so far has been based on control effectiveness alone without regard to the forces required to reverse the controls. As previously mentioned, for all tests, sufficient force was applied to the controls to move them fully and rapidly. Sufficient force must be applied to the airplane controls to move them in a similar manner in order for the model and airplane results to be comparable.

Results of tests indicate that a force of approximately 125 pounds (full-scale) was required to reverse the rudder. This force is within the capabilities of a pilot (ref. 5). Because of lack of detail in the rudder balance of the model, of inertia mass-balance effects, and of scale effect, these results are only a qualitative indication of the actual forces that may be experienced. Aileron and elevator forces were not investigated because they could not be determined as readily as the rudder. It would be expected, however, that inasmuch as the ailerons

and elevator only have to go to neutral for recovery, the control forces· would not be excessive.

Recommended Spin-Recovery Technique

Based on the results obtained with the model, the following recovery technique is recommended for all ·loadings and conditions of the airplane for both erect and inverted spins with the propeller windmilling:

Reverse the rudder briskly from full with the spin to full against the spin and simultaneously move the stick laterally and longitudinally to neutral.

Spin-Recovery Parachutes

The results of tests performed with flat-type spin-recovery parachutes attached to the tail of the model are presented in table III. The tests were conducted with the controls set for the criterion spin. Two towline lengths and several sizes of tail parachutes were investigated. With the shorter towline length, 13.8 feet (full-scale), the tail parachute tended to oscillate into the dead-air space over the model and therefore required a rather large flat-type parachute 14.6 feet in diameter (laid-out-flat dimension) to insure consistently satisfactory recoveries. In addition, when the large parachutes were opened, the initial shock tended to whip the model around for a few turns before the model dived out. However, with a longer towline length equivalent to 27.5 feet, full-scale, the parachute canopy did not appear to be influenced by the dead-air region over the model and a parachute 11.5 feet (laid out flat) in diameter satisfactorily terminated spins. It is recommended that an 11.5-foot flat-type conventional parachute attached to a 27.5-foot towline (or an equivalent stable parachute) be used as an emergency recovery device on the full-scale airplane. The· drag coefficient of the tail parachute investigated was approximately 0.73. If a parachute with a different drag coefficient is used, a corresponding adjustment will be required in parachute size. The parachutes used in this investigation were flat-type parachutes which are unstable. If the full-scale parachute installation is to be tested ·in level flight before spins are attempted, the usual low porosity of conventional flat-type parachutes may cause violent pitching and yawing gyrations. Use of a higher porosity stable-type parachute, described in reference 6, will eliminate this possibility and may be more desirable than a conventional-type parachute, provided the opening characteristics of the higher porosity parachutes are not adversely affected at the airspeed at which it is to be tested (ref. 7).

Tumbling Tests

Tumbling tests were conducted with the model in the take-off loading with fuel and ammunition (loading 15 in table II) with ailerons and rudder at neutral. The model was investigated with the wing-tip pods installed and with the propeller simulated at a 70° blade angle. The results of the tests (not presented in tabular form) showed that the model had no tendency to tumble at any elevator setting.

When the model was launched with forced pitching rotation, the tumbling imparted to the model was damped out after about 1 turn and a pitching oscillation encountered by the model after the tumbling had ceased was damped out rapidly. When launched from a whip-stall attitude, the model pitched its nose downward and oscillated in pitch for a short period before diving out. No other loading or propeller condition was investigated because the tumbling of the model damped out extremely rapidly for the loading tested and also because tumble tests on a different model using propellers similar to the XFV-1 propellers indicated essentially the same amount of damping with propellers removed or installed. It would also be expected that the XFV-1 should resist tumbling for any of the loading conditions tabulated in table II with propellers windmilling at any blade angle. If during the development of the XFV-1 airplane the center of gravity should move somewhat rearward of the extreme rearward position indicated in table II, it would be expected that the XFV-1 should still resist tumbling inasmuch as reference 8 indicates that airplanes with tails do not tumble even when extreme static instability exists.

CONCLUSIONS

Based on the results of tests of a 1/25-scale model of the Lockheed XFV-1 airplane with a windmilling propeller simulated, the following conclusions regarding the spin and recovery characteristics and the tumbling tendencies of the airplane at an altitude of 20,000 feet are made:

1. The spin-recovery characteristics of the airplane will be satisfactory for all loadings from both erect and inverted spins if the following recovery technique is used: brisk rudder reversal from full with to full against the spin accompanied by simultaneous lateral and longitudinal movement of the stick to neutral.

2. An 11.5-foot flat-type tail parachute (drag coefficient approximately 0.73) with a 27.5-foot towline will effect satisfactory emergency recoveries from demonstration spins.

3. The rudder pedal force necessary to reverse the rudder for recovery will be within the capabilities of a pilot.

4. The airplane will not tumble for any loading condition.

Langley Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va., July 23, 1953.

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CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR
THE LANDING LOADING WITHOUT PODS (WITH PROPELLER OFF)

[Loading 1 in Table II and Figure 6 $\left(\dfrac{I_X - I_Y}{mb^2} = -835 \times 10^{-4}\right)$; recovery attempted by full

rudder reversal (recovery attempted from, and developed-spin data presented for, rudder-
full-with spins); right erect spins]

a

NO SPIN

Ailerons $\frac{1}{3}$ against

a

NO SPIN

Elevator $\frac{2}{3}$ up

a

NO SPIN

a

NO SPIN

Ailerons $\frac{1}{3}$ with

a

NO SPIN

b

STEEP SPIN	
>330	
$\frac{1}{4}$,	$\frac{1}{4}$

Elevator full up (Stick back)

a

NO SPIN

Ailerons full against (Stick left)

c

STEEP SPIN	
>330	
$\frac{3}{4}$,	$\frac{1}{2}$

Ailerons full with (Stick right)

d

NO SPIN

Elevator full down (Stick forward)

e

NO SPIN

e

NO SPIN

d

NO SPIN

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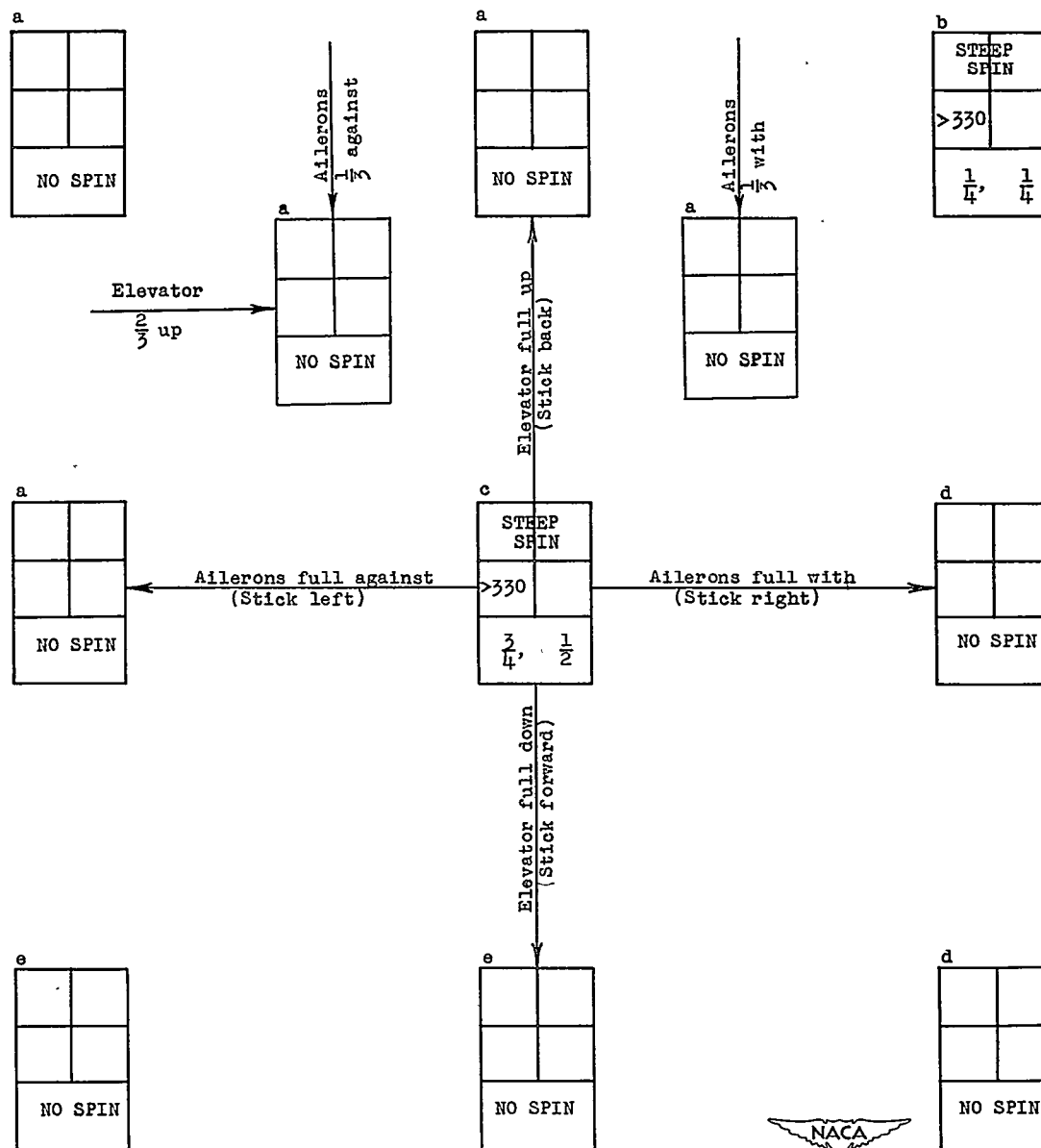
[a]After launching rotation expended, model dives.
[b]Wandering oscillatory spin.
[c]Spin oscillatory in roll and yaw.
[d]After launching rotation expended, model goes
  into a vertical aileron roll.
[e]After launching rotation expended, model dives
  out then pitches inverted.

Model values
converted to
corresponding
full-scale values.
U inner wing up
D inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR
THE LANDING LOADING WITHOUT PODS (WITH 70° PROPELLER BLADE ANGLE SIMULATED)

[Loading 1 in Table II and Figure 6 $\left(\dfrac{I_X - I_Y}{mb^2} = -835 \times 10^{-4}\right)$; recovery attempted by full

rudder reversal except as noted (recovery attempted from, and developed-spin data
presented for, rudder-full-with spins); right erect spins]

[a]After launching rotation expended, model dives.
[b]Whipping spin.
[c]Two conditions possible.
[d]After launching rotation expended, model goes
into a steep spiral.
[e]Recovery attempted by reversing the rudders from
full with to $\frac{2}{3}$ against the spin.
[f]After launching rotation expended, model goes
into a vertical aileron roll.

Model values
converted to
corresponding
full-scale values.
U   inner wing up
D   inner wing down

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL FOR THE TAKE-OFF
LOADING WITH FUEL AND AMMUNITION (WITH 70° PROPELLER BLADE ANGLE SIMULATED)

$\left[\text{Loading 15 in Table II and Figure 6} \left(\dfrac{I_X - I_Y}{mb^2} = -510 \times 10^{-4} \right); \text{recovery attempted by full}\right.$

rudder reversal except as noted (recovery attempted from, and developed-spin data
presented for, rudder-full-with spins); right erect spin]

Ailerons ⅓ with

Elevator ⅔ up

Elevator full up (Stick back)

Ailerons full against (Stick left)

Ailerons full with (Stick right)

Elevator full down (Stick forward)

a   NO SPIN

a   NO SPIN

a   NO SPIN

g   NO SPIN

b		
56	2D	STEEP SPIN
241	0.30	>330
c 1¾,	c 2	c ¼

b,d		
65	10D 3U	STEEP SPIN
227	0.33	>330
e 2,	e 3¾	e ½, e ¾
2,	2	
f 1½,	f 1¾	

d	
52 67	8D 4U
227	0.31
1,	1¼

aAfter launching rotation expended, model dives.
bTwo conditions possible.
cRecovers in a steep spiral.
dOscillatory spin, range or average values given.
eRecovery attempted by reversing the rudders from full with to ⅔ against the spin.
fRecovery attempted by reversing the rudders from full with to ⅔ against the spin and simultaneously moving ailerons and elevators to neutral.
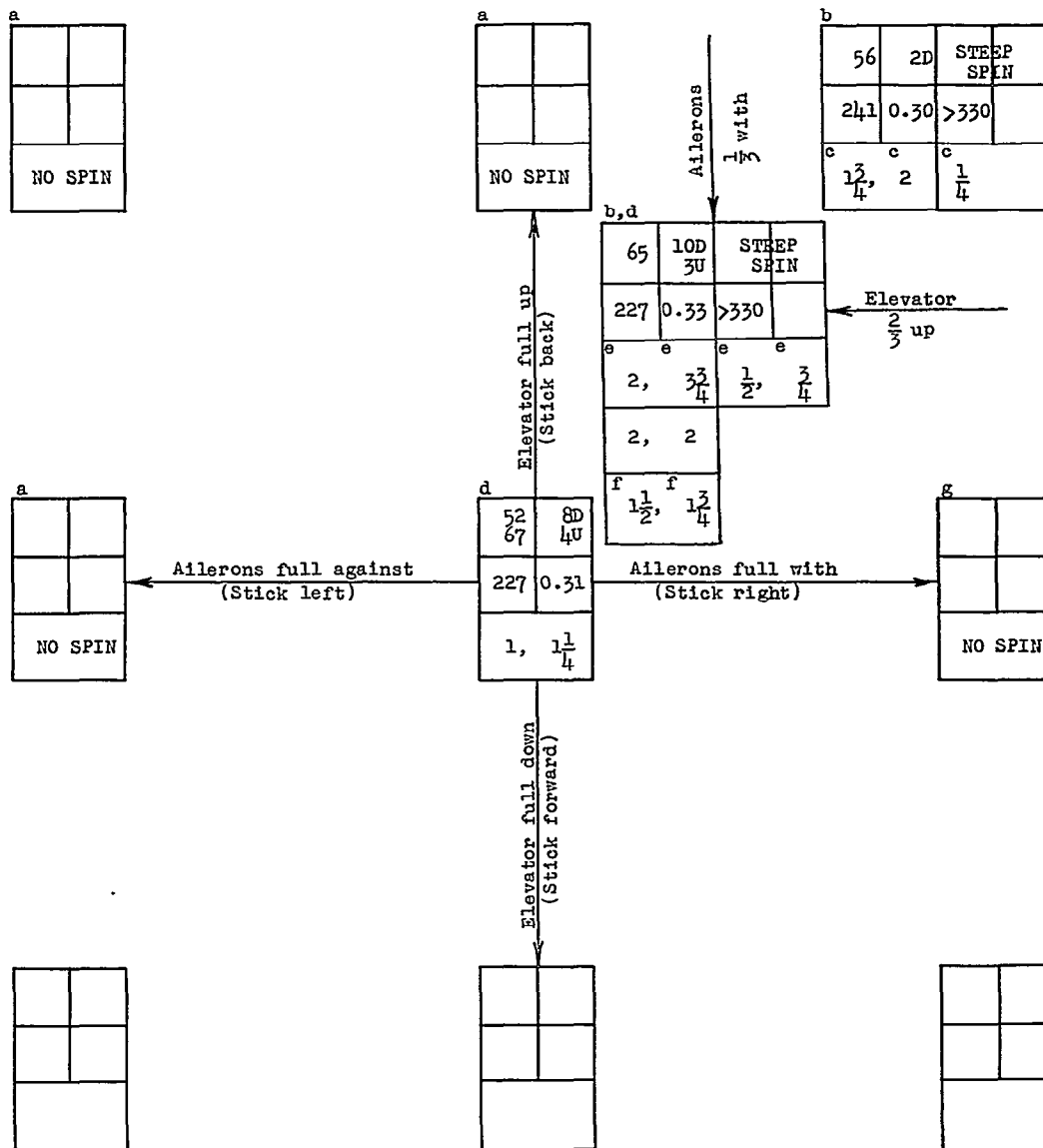gAfter launching rotation expended, model goes into a vertical aileron roll.

Model values converted to corresponding full-scale values.
U   inner wing up
D   inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE LOCKHEED XFV-1

MODEL AS SIMULATED ON THE $\frac{1}{25}$ - SCALE SPIN MODEL

Length, over-all, ft 37.5

Wing:
  Span, ft 27.5
  Area, sq ft 246
  Airfoil section . . . . NACA 64A206 (Mod.)
  Mean aerodynamic chord, in. 116.5
  Leading edge $\bar{c}$ behind wing apex, in. 18.175
  Tip chord, in. 53
  Root chord, in. 162
  Incidence, deg 1
  Dihedral, deg 5
  Taper ratio 0.327
  Effective aspect ratio 3
  Distance from the center of gravity for the take-off
    loading (with fuel and ammunition) to intersection
    of control hinge line and fuselage center line, in. 178.80

Tail surfaces:
  Span, ft 12.25
  Total area, sq ft 169
  Area — 4 fixed surfaces, sq ft 136.2
  Area — movable surfaces, sq ft 32.8
  Airfoil section . . . . NACA 65A007
  Incidence, deg . . . . -4

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS

POSSIBLE ON THE LOCKHEED XFV-1 AIRPLANE AND FOR THE

LOADINGS TESTED ON THE $\frac{1}{25}$ - SCALE MODEL

[Model values are given as corresponding full-scale values,
moments of inertia are given about the center of gravity]

No.	Loading		Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft²			Mass parameters		
				$x/\bar{c}$	$z/\bar{c}$	Sea level	20,000 ft	I_X	I_Y	I_Z	$\dfrac{I_X - I_Y}{mb^2}$	$\dfrac{I_Y - I_Z}{mb^2}$	$\dfrac{I_Z - I_X}{mb^2}$
Airplane values													
1	Landing	Pods off	10,664	0.0591	0.0571	20.57	38.62	2,841	23,387	24,855	-820×10^{-4}	-59×10^{-4}	879×10^{-4}
2	Design		11,809	.0682	.0454	22.75	42.71	2,972	23,410	24,924	-737	-55	792
3	Take-off		12,984	.0694	.0316	25.05	47.02	3,182	23,476	25,070	-666	-52	718
4	Landing	Pods on and empty	10,844	.0630	.0547	20.93	39.29	3,903	23,424	25,937	-766	-99	865
5	Design		11,989	.0715	.0434	23.12	43.40	4,033	23,444	26,004	-689	-91	780
6	Take-off		13,164	.0725	.0300	25.41	47.70	4,241	23,501	26,143	-623	-85	708
7	Landing	Pods on and full	11,438	.0712	.0475	22.07	41.44	7,433	23,504	29,473	-598	-222	820
8	Design		12,583	.0785	.0373	24.29	45.59	7,556	23,518	29,541	-540	-204	744
9	Take-off		13,758	.0789	.0250	26.56	49.85	7,759	23,575	29,685	-489	-189	678
10	Hovering	With fuel less ammunition	13,592	.0391	.0405	26.23	49.25	7,972	28,277	34,589	-636	-198	834
11	Design		14,572	.0445	.0334	28.13	52.80	8,075	28,312	34,676	-591	-186	777
12	Take-off		15,790	.0474	.0225	30.48	57.21	8,279	28,373	34,830	-542	-174	716
13	Hovering	With fuel with ammunition	14,002	.0454	.0386	27.03	50.73	8,582	28,339	35,258	-601	-210	811
14	Design		14,982	.0502	.0318	28.92	54.29	8,685	28,375	35,346	-560	-198	758
15	Take-off		16,200	.0526	.0214	31.27	58.70	8,890	28,436	35,501	-514	-186	700
Model values													
1	Landing	Pods off	10,663	0.0584	0.0554	20.57	38.62	2,869	23,760	24,859	-835	-44	879
15	Take-off	With fuel with ammunition	16,097	.0521	.0483	31.08	58.34	9,554	28,847	35,787	-510	-183	693

TABLE III.- SPIN-RECOVERY PARACHUTE DATA OBTAINED WITH A

1/25-SCALE MODEL OF THE LOCKHEED XFV-1 AIRPLANE

[Take-off loading with fuel and ammunition (loading 15 in table II and fig. 6); rudder fixed full with the spin and recovery attempted by opening the parachute only; model values converted to corresponding full-scale values; C_D of parachutes approximately 0.73; right erect spins]

Parachute diameter, ft	Towline length, ft	Ailerons	Elevator	Turns for recovery
9.4	13.8	10° with	20° up	3, 3
10.4	13.8	10° with	20° up	2, 2, $1\frac{1}{2}$, $1\frac{1}{2}$
11.5	13.8	10° with	20° up	2, $2\frac{1}{2}$, 2, [a]4, 3
12.5	13.8	10° with	20° up	1, 1, 1, 1, 1
13.5	13.8	10° with	20° up	$2\frac{1}{2}$, 2, 2, 2
14.6	13.8	10° with	20° up	1, 2, 1, 1, 1, 1
16.7	13.8	10° with	20° up	1, $1\frac{1}{4}$, $\frac{3}{4}$, 1, 1
11.5	27.5	10° with	20° up	1, $1\frac{1}{2}$, $1\frac{1}{2}$, 1, $1\frac{1}{2}$
12.5	27.5	10° with	20° up	1, 1, $1\frac{1}{2}$, 1, 1
13.5	27.5	10° with	20° up	1, 1, $1\frac{1}{2}$, 2, $1\frac{1}{2}$
14.6	27.5	10° with	20° up	$1\frac{1}{2}$, 1, 1, 1
16.7	27.5	10° with	20° up	$\frac{1}{2}$, $\frac{1}{2}$, $1\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$

[a]Chute oscillated into dead-air region over model.
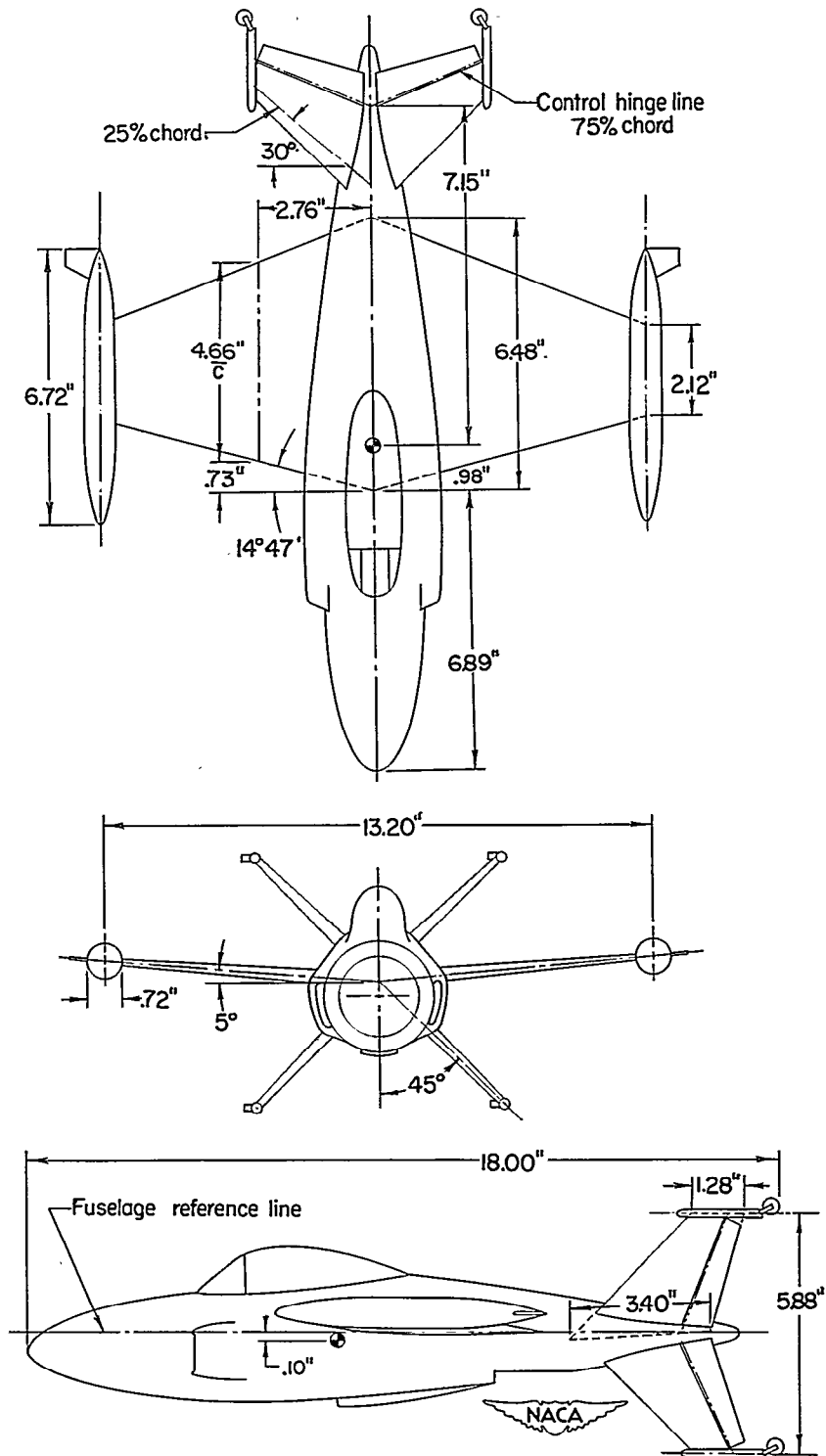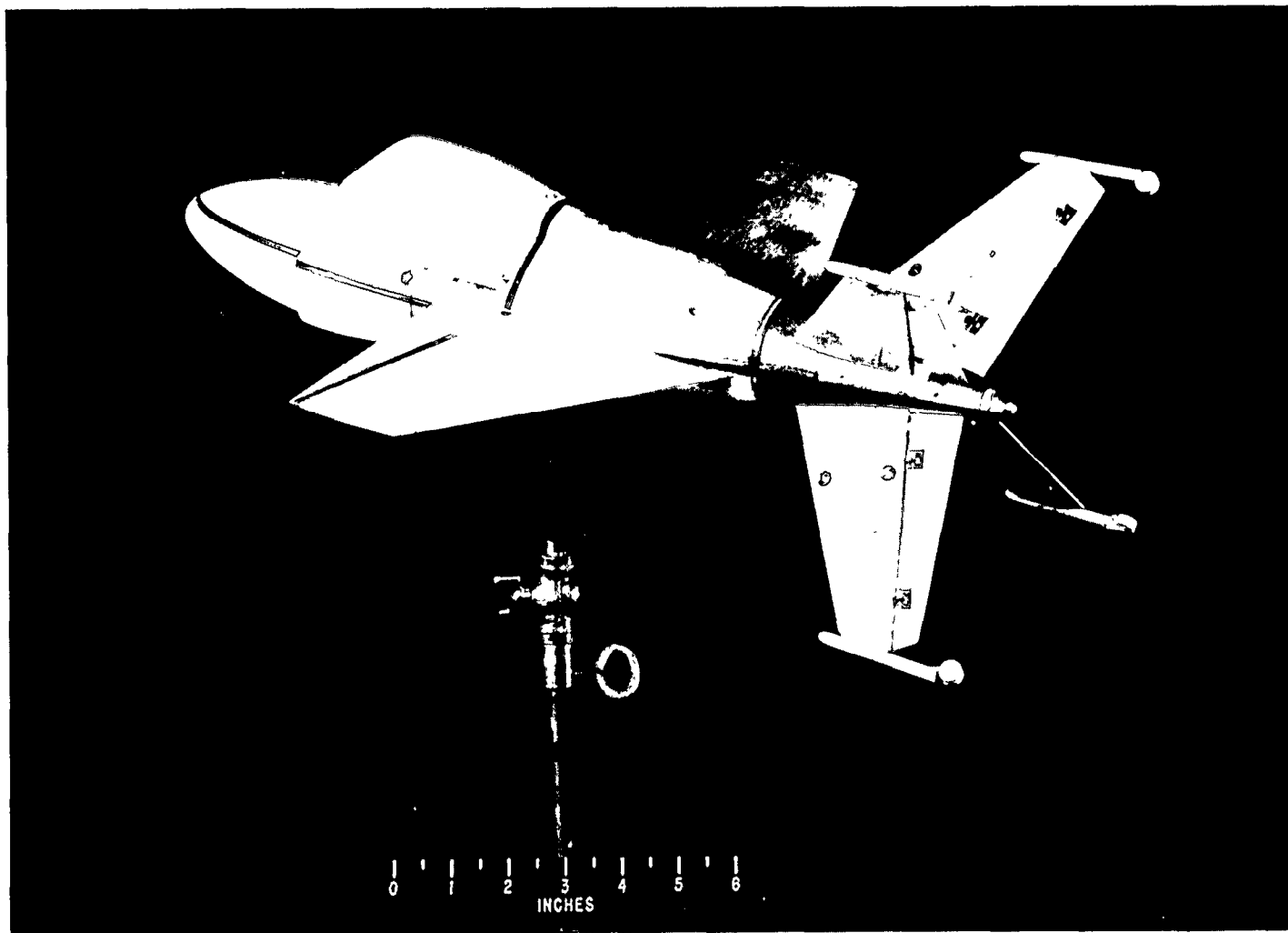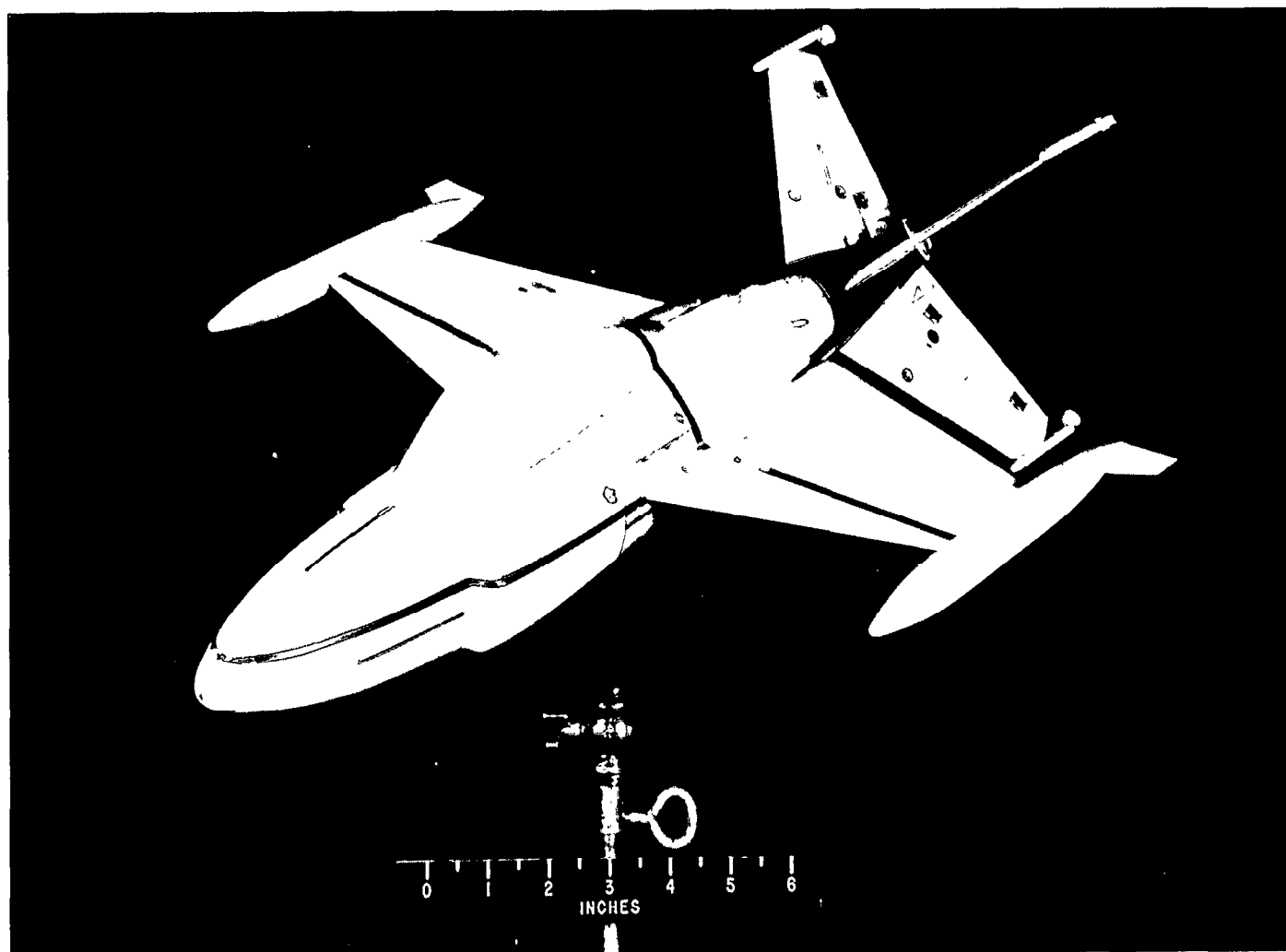
Figure 1.- Three-view drawing of the 1/25-scale model of the Lockheed XFV-1 airplane as tested in the Langley 20-foot free-spinning tunnel. Dimensions are model values. Center-of-gravity position shown is for the take-off loading (with fuel and ammunition).

L-77855

Figure 2.- The 1/25-scale model of the Lockheed XFV-1 airplane with wing-tip pods removed as tested in the Langley 20-foot free-spinning tunnel.

L-77858

Figure 3.- The 1/25-scale model of the Lockheed XFV-1 airplane with pods
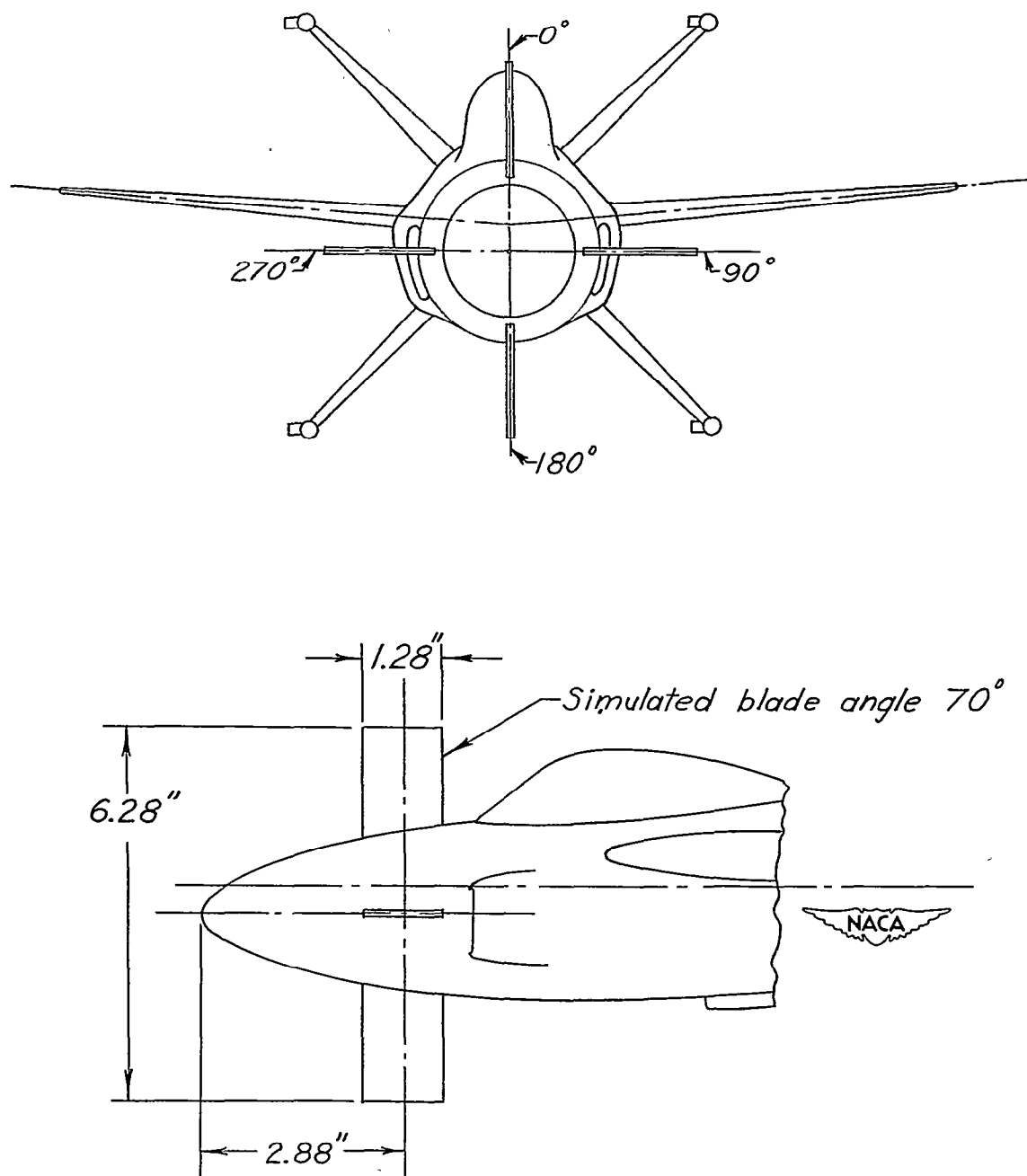on as tested in the Langley 20-foot free-spinning tunnel.

Figure 4.- Drawing of the fin area simulating the propeller as tested on the 1/25-scale model of the Lockheed XFV-1 airplane. Dimensions are model values.

L-79823

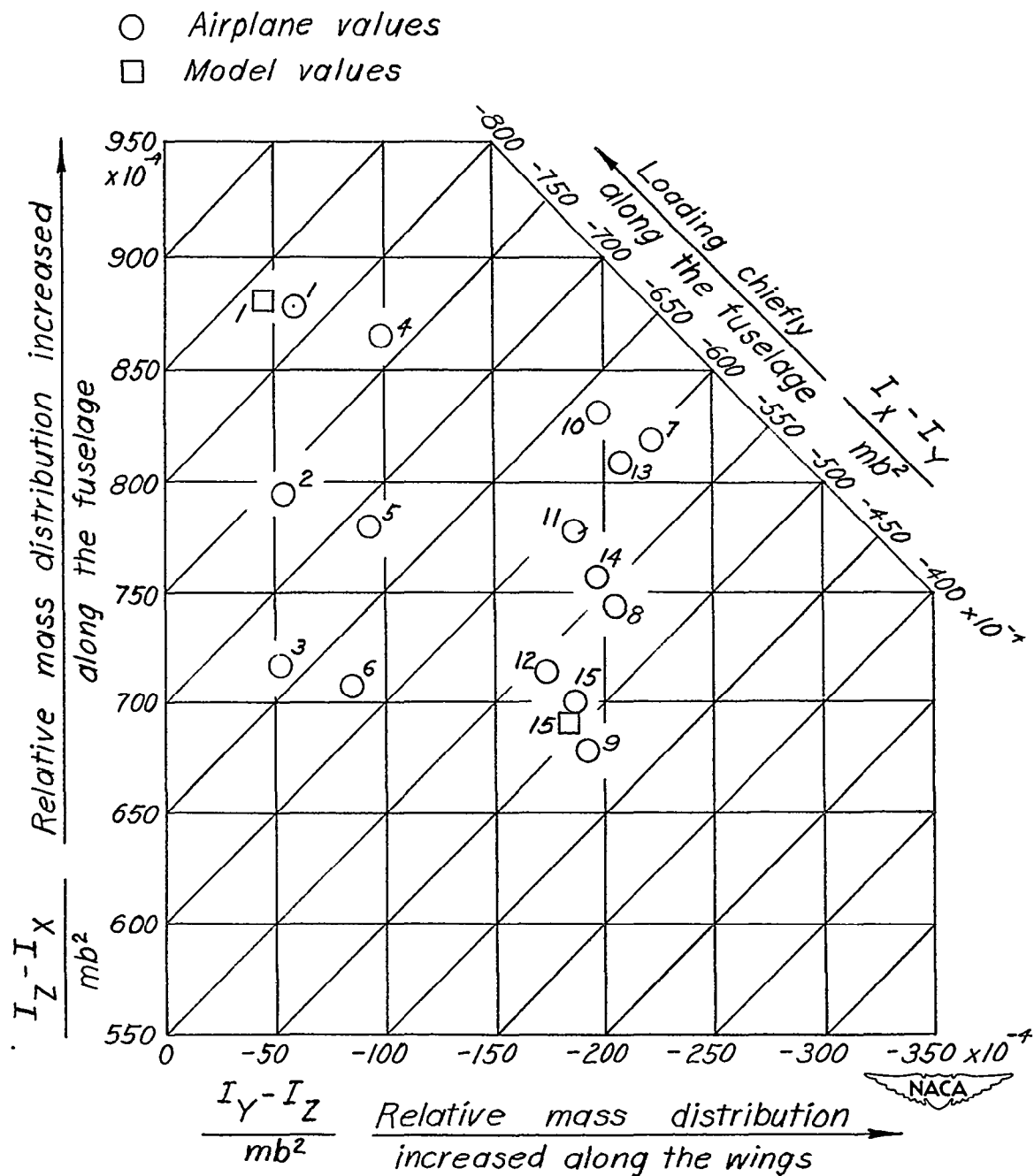Figure 5.- Photograph of the model spinning in the Langley 20-foot free-
spinning tunnel.

Figure 6.- Mass parameters for loadings possible on the Lockheed XFV-1
airplane and for the loadings tested on the 1/25-scale model. (Points
correspond to numbered loadings in table II.)